7 Bicycle Paths

Constructing bicycle paths is one way to create new recreational opportunities. It also can help bicyclists surmount major barriers or hazards.

Introduction

Bicycle paths are trails generally located on exclusive rights-of-way and with minimal cross flow by motor vehicles. Bicycle paths can serve a variety of purposes. For example, a connecting trail between two cul-de-sac streets can provide commuter bicyclists with a shortcut through a residential neighborhood or around a barrier.

Located in a park, a bicycle path can provide a wide variety of users with an enjoyable recreational experience. Bicycle paths can be located along abandoned railroad rights-of-way, the banks of rivers and other similar linear corridors. Bicycle paths also can provide bicycle access to areas that are otherwise served only by limited access highways closed to bicycles. Appropriate locations can be identified during the planning process.

Bicycle paths should be thought of as non-motorized extensions of the highway system intended for the exclusive or preferential use of bicycles. It is important for designers to remember that the bicycle is a vehicle and that close attention to accepted design criteria is necessary for the provision of safe facilities. While there are many similarities between design criteria for bicycle paths and those for highways (e.g., in determining horizontal alignment, sight distance requirements and signing), some criteria (e.g., horizontal clearance requirements, grades and pavement structure) are dictated by operating characteristics of bicycles that are substantially different from those of motor vehicles. The designer should always be conscious of the similarities and differences and how these influence the design of bicycle paths. The following sections provide guidance for designing a safe and functional bicycle path.

Separating paths and highways

When two-way bicycle paths are located immediately adjacent to a roadway, operational problems may occur. The following are some problems with bike paths located immediately adjacent to roadways.

(1.) Unless paired, they require one direction of bicycle traffic to ride against traffic, contrary to normal rules of the road.

(2.) When the path ends, bicyclists going against traffic will tend to continue to travel on the wrong side of the street. Likewise, bicyclists approaching a bicycle path often travel on the wrong side of the street to get to the path. Wrong way riding is a major cause of bicycle/automobile crashes and should be discouraged at every opportunity.

(3.) At intersections, motorists entering or crossing the highway often will not notice bicyclists coming from their right, as they are not expecting contra-flow vehicles. Even bicyclists coming from the left often go unnoticed, especially when sight distances are poor.

(4.) When constructed in narrow roadway right-of-way, the shoulder is often sacrificed, thereby decreasing safety for motorists and bicyclists using the roadway.

(5.) Many bicyclists will use the highway instead of the bicycle path because they have found the highway to be safer, more convenient or better maintained. Bicyclists using the highway are often subjected to harassment by motorists who feel that in all cases bicyclists should be on the path instead.

(6.) Bicyclists using the bicycle path generally are required to stop or yield at all cross streets and driveways, while bicyclists using the highway usually have priority over cross traffic because they have the same right-of-way as motorists.

(7.) Stopped cross street motor vehicle traffic or vehicles exiting side streets or driveways may block the path crossing.

(8.) Because of the closeness of motor vehicle traffic to opposing bicycle traffic, barriers are often necessary to keep motor vehicles out of bicycle paths and bicyclists out of traffic lanes. These barriers can be a hazard to bicyclists and motorists, can complicate maintenance of the facility and can cause other problems as well.

For these reasons, wide curb lanes, bicycle lanes or bicycle routes may be the best way to accommodate bicycle traffic along highway corridors depending upon traffic conditions.

Multipurpose recreational trails

In some instances, it may be appropriate for recreational agencies to develop multipurpose recreational trails – for hikers, joggers, equestrians, bicyclists, etc. Many of these trails will not be paved and will not meet the standards for bicycle paths presented in this guide. As such, these facilities should not be signed as bikeways. Rather, they should be designated as recreational trails (or similar designation), along with regulatory signing to restrict motor vehicles, as appropriate. If recreational trails are to serve primarily bicycle travel, they should be developed in accordance with standards for bicycle paths.

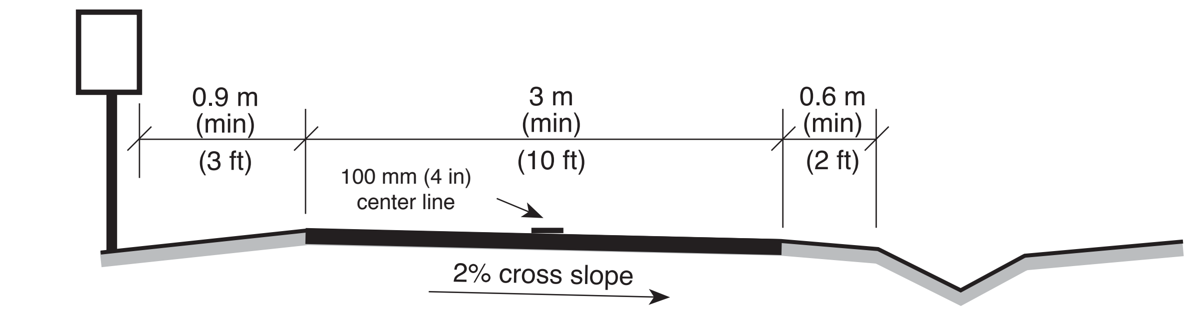
Width and clearance

Paved width: The paved width and the operating width required for a bicycle path are primary design considerations. Under most conditions, the minimum paved width for a two-directional bicycle path is 3 m (10 ft) Paths narrower than 3 m (10 ft) are not recommended as they do not permit safe and frequent passing opportunities where there is high bicycle use, especially where pedestrian use is frequent. Also, a narrow path is subject to pavement edge damage from maintenance vehicle loading conditions. (A segment of path less than 3 m (10 ft) wide may be acceptable or necessary for short distances, such as when passing between buildings or utility poles that cannot be moved, or when crossing bridges that cannot be modified, or unusual items such as above-ground pipes to underground storage tanks. These should be treated on a case-by-case basis and signed in accordance with the MUTCD.)

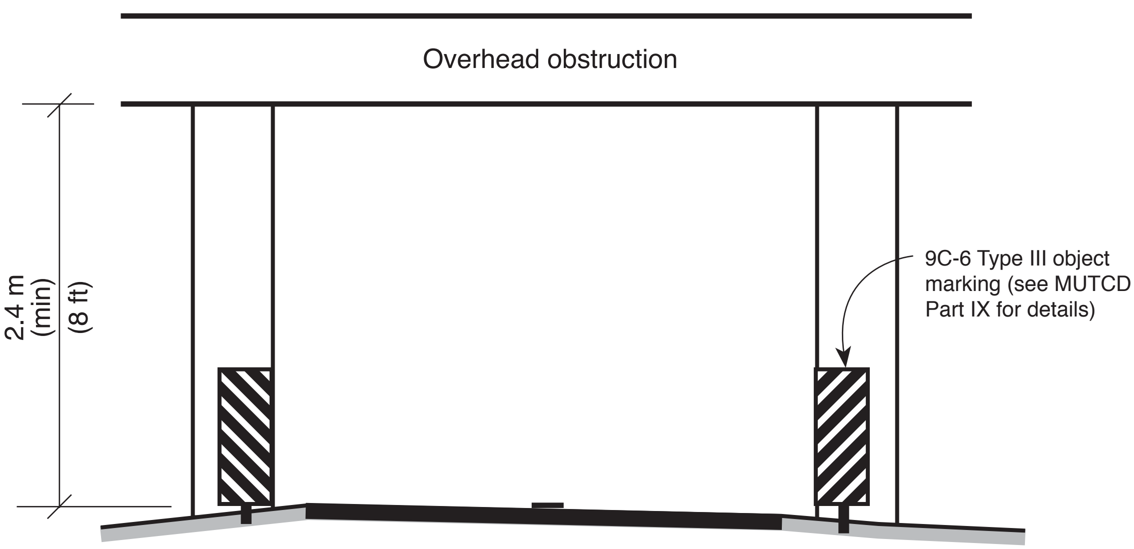
In many cases, it may be desirable to increase the width of a bicycle path to 3.6 m (12 ft). For example, wider paths may be needed in cases involving substantial bicycle volume, probable shared use with joggers and other pedestrians, use by large maintenance vehicles, steep grades and locations where bicyclists are likely to ride two abreast.

One-way bicycle paths often will be used as two-way facilities unless effective measures are taken to assure one-way operation. For this reason, one-way paths are not recommended.

Horizontal clearances: A minimum 0.6 m (2 ft) wide graded area should be maintained adjacent to both sides of the pavement (see Figure 7-1). However, 0.9 m (3 ft) or more is desirable to provide clearance from trees, abutments, piers, polls, walls, fences, box culverts, guardrails or other lateral obstructions. A wider graded area on either side of the bicycle path can serve as a separate jogging path. If adequate clearance cannot be maintained between the path and vertical barriers or other features causing bikeway constriction, a warning sign, as described in Figure 7-1, should be used in advance of the hazard with a Type I, II or III object marker at the location of the hazard



Typical bicycle path cross section



Bicycle path with overhead and adjacent obstructions

(W5-4 "Bikeway Narrows" sign should be used at least 15 meters (50 feet) in advance of obstruction)

Figure 7-1: Bicycle path cross sections showing widths, clearances, cross slopes and center line marking

Source: Guide to the Development of New Bicycle Facilities, AASHTO, 1991 and MUTCD Part IX.

(see Part 9C-6 of the MUTCD for diagrams). This treatment should be used only where unavoidable and is by no means a substitute for good design.

A wide separation between a bicycle path and canals, ditches or other significant depressions is essential for safety. A minimum 1.5 m (5 ft) separation from the edge of the bike path pavement to the top of the slope is desirable. If this is not possible, a physical barrier such as dense shrubbery or a chain link fence should be provided (see Figure 7-2).

A wide separation between a bicycle path and any nearby highway is desirable to confirm

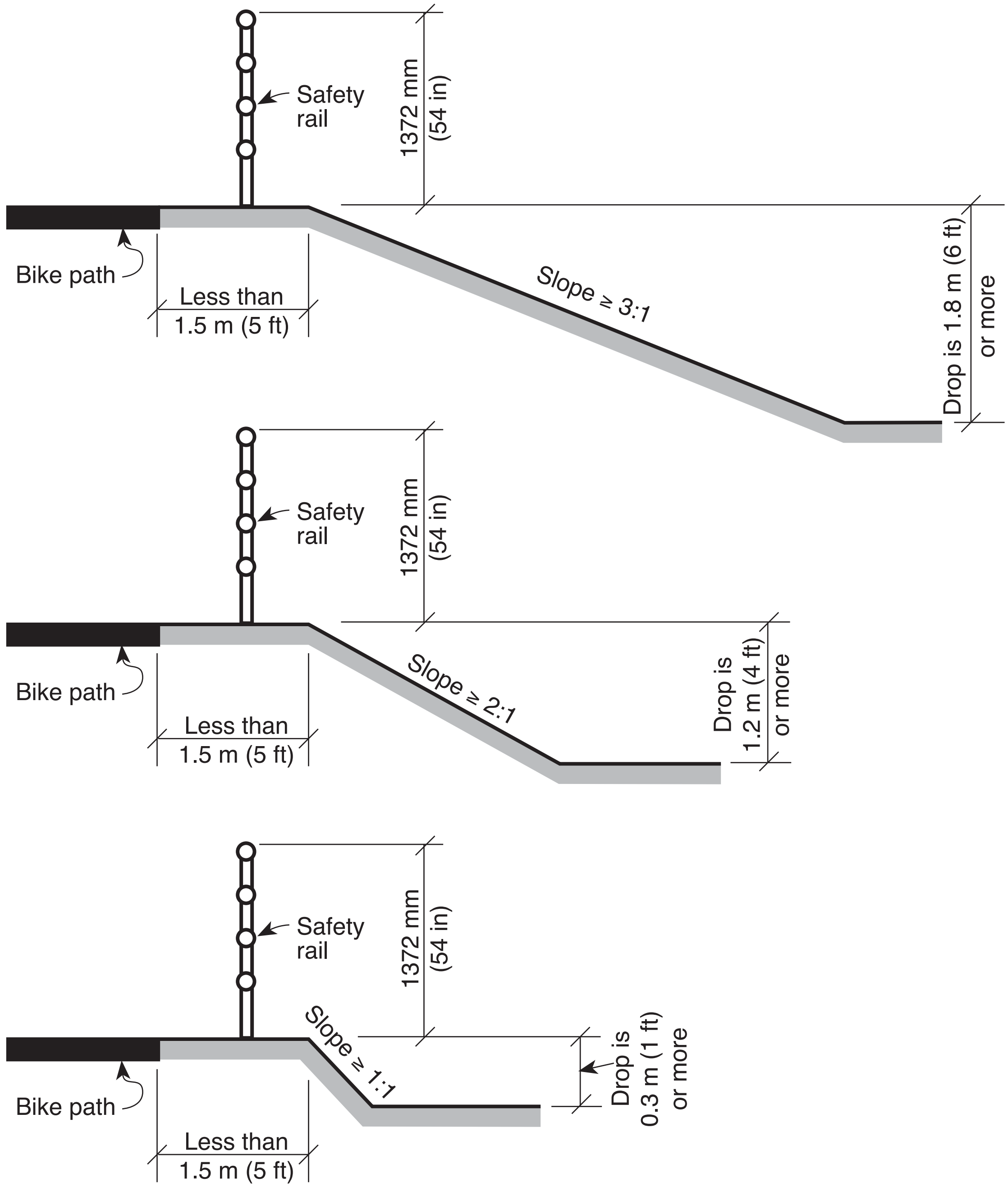


Figure 7-2: Safety rail between bicycle path and adjacent slope.

Source: Arizona Bicycle Facilities Planning & Design Guidelines, AZDOT, 1988.

to both the bicyclist and the motorist that the bicycle path functions as an independent facility for bicycles. When this is not possible and the distance between the edge of the roadway and the bicycle path is less than 1.5 m (5 ft) then a suitable positive barrier should be provided.

Such dividers serve to prevent bicyclists from making unwanted movements between the path and the highway shoulder and to reinforce the concept that the bicycle path is an independent facility. Where used, the divider should be a minimum of 1.35 m (54 in) high, to prevent bicyclists from toppling over it. Such a situation should be treated as a special case and appropriate roadside design and warning measures taken. Where the path approaches crossing roadways or driveways, the barrier should be modified as necessary to enhance visibility between bicyclists and motorists.

Vertical clearances: The vertical clearance to obstructions should be a minimum of 2.4 m (8 ft) (see Figure 7-1). However, vertical clearance may need to be greater to permit passage of maintenance vehicles and, in undercrossings and tunnels, a clearance of 3 m (10 ft) is desirable for adequate vertical shy distance.

Design speed

The speed that a bicyclist travels is dependent on several factors, including the type and condition of the bicycle, the purpose of the trip, the condition and location of the bicycle path, the presence of other traffic, the speed and direction of the wind and the physical condition of the bicyclist. Bicycle paths should be designed for a selected speed that is at least as high as the preferred speed of the faster bicyclists. In general, a minimum design speed of 35 km/h (20 mph) should be used; however, when the grade exceeds four percent, or where strong prevailing tailwinds exist, a design speed of 50 km/h (30 mph) is advisable.

Speed bumps or similar surface obstructions, intended to slow down bicyclists in advance of intersections, should not be used. They may divert a rider's attention from traffic or catch a pedal causing the cyclist to fall.

On unpaved paths, where bicyclists tend to ride slower, a lower design speed of 25 km/h (15 mph) can be used. Similarly, where the grades or the prevailing winds dictate, a higher design speed of 40 km/h (25 mph) can be used. Since bicycles have a higher tendency to skid on unpaved surfaces, horizontal curvature design should take into account lower coefficients of friction. With the growing popularity of mountain bicycles, provision of unpaved trails is likely to increase. However, little research has been done on the phenomenon. Quite possibly, speeds on some types of unpaved trails will equal or exceed those on paved trails, especially where there are significant grades. The engineer should exercise proper care when dealing with this new area of design.

Horizontal alignment and superelevation

The minimum radius of curvature negotiable by a bicycle is a function of the superelevation rate of the bicycle path surface, the coefficient of friction between the bicycle tires and the bicycle path surface, the speed of the bicycle and the amount of lean the bicyclist can handle. Leaning is an important aspect of bicycle turns; the farther over a bicyclist can lean in a turn, the sharper a curve he/she can negotiate, given the limitations of friction. However, novice bicyclists are less able to lean over safely and, as a result, will be unable to negotiate a curve at the same speed as a more skilled rider. For this reason, a conservative approach to setting curve radius is important.

The minimum design radius of curvature can be derived from the following formula:

$$R_{min} = \frac{V2}{15\ (e + f)}$$

Where
R = Minimum radius of curvature (ft),
V = Design speed (mph),
e = Rate of superelevation (ft/ft),
f = coefficient of friction.

For most bicycle path applications, the superelevation rate will vary from a minimum of +2% (the minimum necessary to encourage adequate drainage) to a maximum of approximately +5% (beyond which maneuvering difficulties by slow bicyclists and adult tricyclists might be expected). The

minimum superelevation rate of +2% will be adequate for most considerations and will simplify construction. Negative superelevations are to be avoided, since they have the same effect on bicyclists' stability as leaning farther than intended in
a turn.

The coefficient of friction depends upon bicycle speed; surface type, roughness and condition; tire type and condition; and whether the surface is wet or dry. Friction factors used for design should be selected based upon the point at which centrifugal force causes the bicyclist to recognize a feeling of discomfort and instinctively act to avoid higher speed. Extrapolating from values used in highway design, design friction factors for paved bicycle paths can be assumed to vary from 0.30 at 23 km/h (15 mph) to 0.22 at 50 km/h (30 mph). Although there are no data available for unpaved surfaces, it is suggested that friction factors be reduced by 50 percent to allow a sufficient margin of safety.

Based upon a superelevation rate (e) of +2%, minimum radii of curvature can be selected from Figure 7-3 below.

(e= +2%)

Design Speed - V km/h (mph)	Friction Factor - f	Design radius - R m (ft)
30 (20)	0.27	30 (95)
40 (25)	0.25	50 (155)
50 (30)	0.22	80 (250)
60 (35)	0.19	120 (390)
65 (40)	0.17	175 (565)

Figure 7-3: Design radii for paved bicycle paths.

Occasionally, designers are tempted to add curves for the purpose of controlling bicyclist speed or to provide some variation in the path alignment. While sometimes successful, this approach may lead bicyclists to cut corners when the resulting alignment appears either arbitrary or unsafe at typical approach speeds. Further, if the curve has a significantly lower design speed than the connecting trail, cyclists may misjudge the appropriate approach speed and leave the trail.

When substandard radius curves must be used on bicycle paths because of right-of-way, topographical or other considerations, standard curve warning signs and supplemental pavement markings – such as a solid yellow center line – should be installed in accordance with the MUTCD.

The negative effects of substandard curves can also be partially offset by widening the pavement through the curves (see Figure 7-4). The additional pavement may be added on either the inside or outside of the curve.

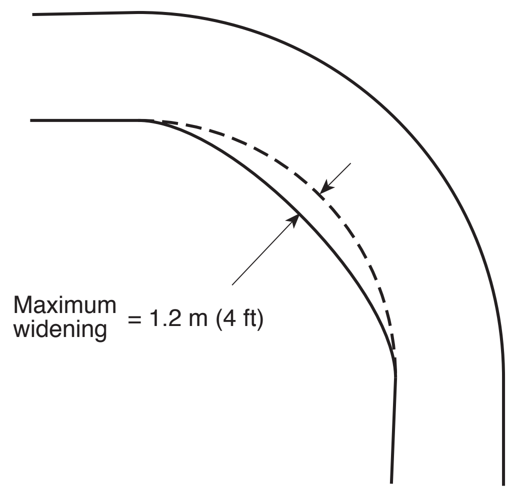


Figure 7-4: Curve widening may partially offset the effects of substandard curves.

Grades

Paved bicycle paths generally attract less-skilled and less-knowledgeable bicyclists, so it is important to avoid steep grades in their design. Bicyclists not physically conditioned will be unable to negotiate long, steep uphill grades and, as a result, may well dismount to walk up hill. For a bicycle path to be considered an acceptable alternative, it should have approximately the same amount of climbing as the roadways serving the same destinations. If it includes significantly more difficult climbs, few bicyclists will use it.

Since novice bicyclists often ride poorly-maintained bicycles and have difficulty in using their brakes for effective speed control, long downgrades can cause problems. For this reason, it is especially important to carefully consider design speed, curve radius, sight distance allowances and intersection location on lower sections of hills.

The maximum desirable grade rate recommended for bike paths is five percent. It is desirable that sustained grades be limited to two percent because of the wide range of riders to be accommodated.

Grades greater than five percent are undesirable. However, where terrain dictates, grades over five percent and less than 150 m (500 ft) long are acceptable when a higher design speed is used and additional width is provided. Grades steeper than three percent may not be practical for bicycle paths with crushed stone surfaces.

Sight distance

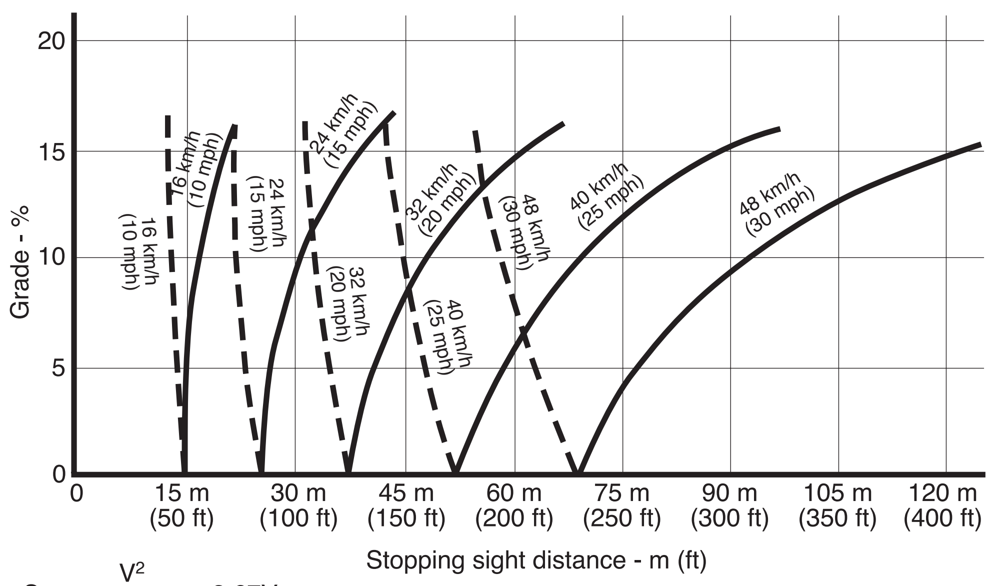
To provide bicyclists with an opportunity to see and react to the unexpected, a bicycle path should be designed with adequate stopping sight distances. The distance required to bring a bicycle to a full controlled stop is a function of the bicyclist's perception and brake reaction time, the initial speed of the bicycle, the coefficient of friction between the tires and the pavement, and the braking ability of the bicycle.

Figure 7-5 indicates the minimum stopping sight distance for various design speeds and grades based on a total perception and brake reaction time of 2.5 seconds and a coefficient of friction of 0.25 to account for the poor wet-weather braking characteristics of many bicycles. For two-way bicycle paths, the sight distance in the descending direction, that is, where "G" is negative, will control the design.

Figure 7-6 is used to select the minimum length of vertical curve necessary to provide minimum stopping sight distance at various speeds on crests. The eye height of the bicyclist is assumed to be 1.35 m (4.5 ft) and the object height is assumed to be zero to recognize that hazards to bicycle travel exist at pavement level.

Figure 7-7 indicates the minimum clearance that should be used to line-of-sight obstructions for horizontal curves. The desired lateral clearance is obtained by entering Figure 7-7 with the stopping sight distance from Figure 7-5 and the proposed horizontal radius of curvature.

Bicyclists frequently ride abreast of each other on bicycle paths, and on narrow bicycle paths, bicyclists have a tendency to ride near the middle of the path. For these reasons, and because of the serious consequences of a



$$S = \frac{V^2}{30(f \pm G)} + 3.67V$$

Descend (-G)
Ascend (+G)

Where: S = Stopping sight distance - ft
V = Velocity - mph
f = Coefficient of friction (use 0.25)
G = Grade - rise/run

Figure 7-5: Stopping sight distances on bicycle paths.

Source: Guide for the Development of Bicycle Facilities; AASHTO; 1991 head-on bicycle accident, lateral clearances on horizontal curves should be calculated based on the sum of the stopping sight distances for bicyclists traveling in opposite directions around the curve. Where this is not possible or feasible, consideration should be given to widening the path through the curve, installing a yellow center stripe, installing a curve ahead warning sign, in accordance with the MUTCD, or some combination of these alternatives.

Intersections

Intersections are among the most important considerations in bicycle path design. If alternate locations for a bicycle path are available, the route that should be selected is one with the fewest intersections, the most favorable intersection conditions and the one that intersects the quietest cross streets.

For freeway crossings, a grade separation structure will be the only possible or practical treatment. When crossing other highways, providing for turning movements must be considered. In most cases, however, the cost of a grade separation will be prohibitive.

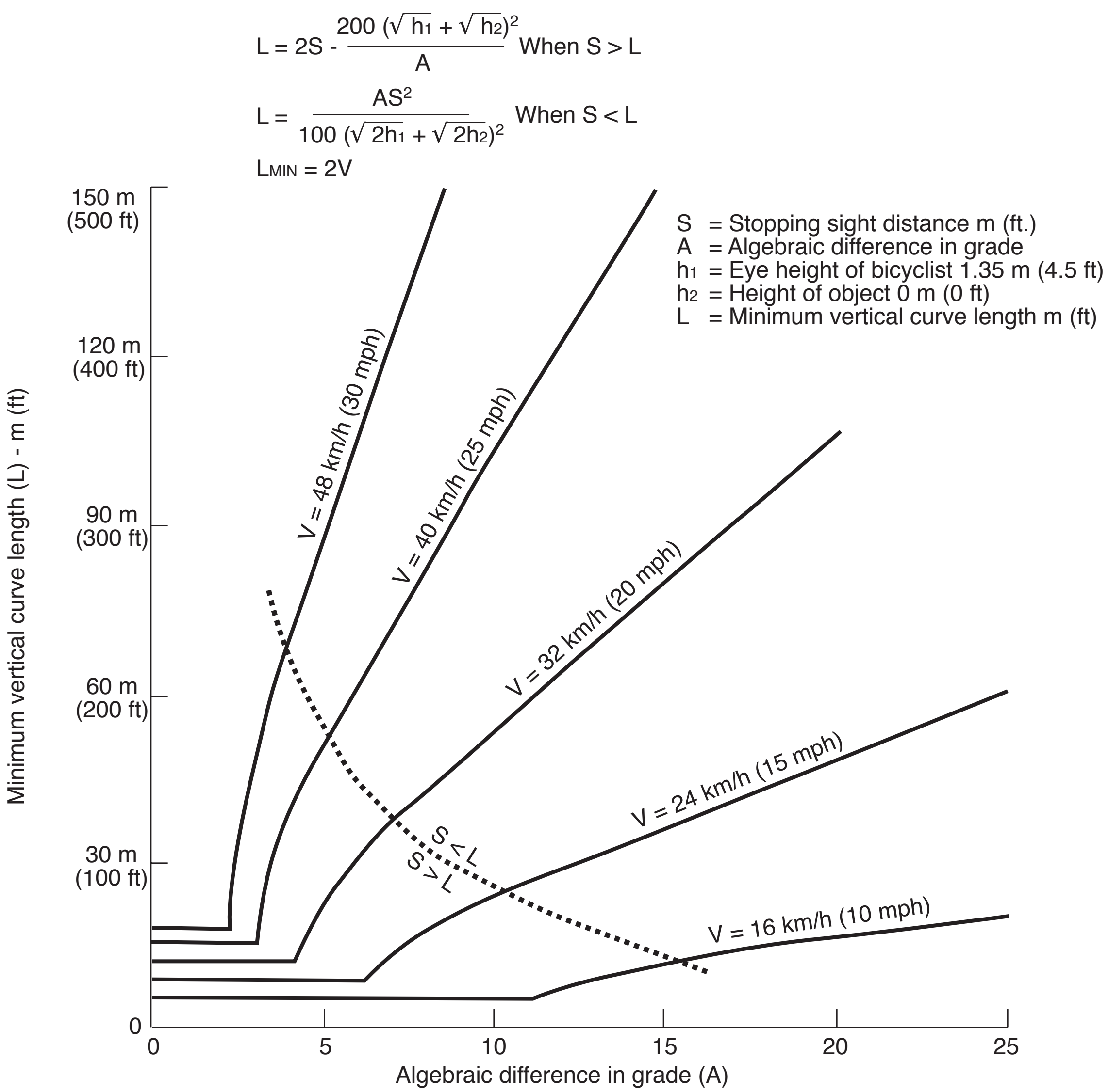


Figure 7-6: Sight distances for crest vertical curves on bicycle paths.

Source: Guide for the Development of Bicycle Facilities; AASHTO, 1991

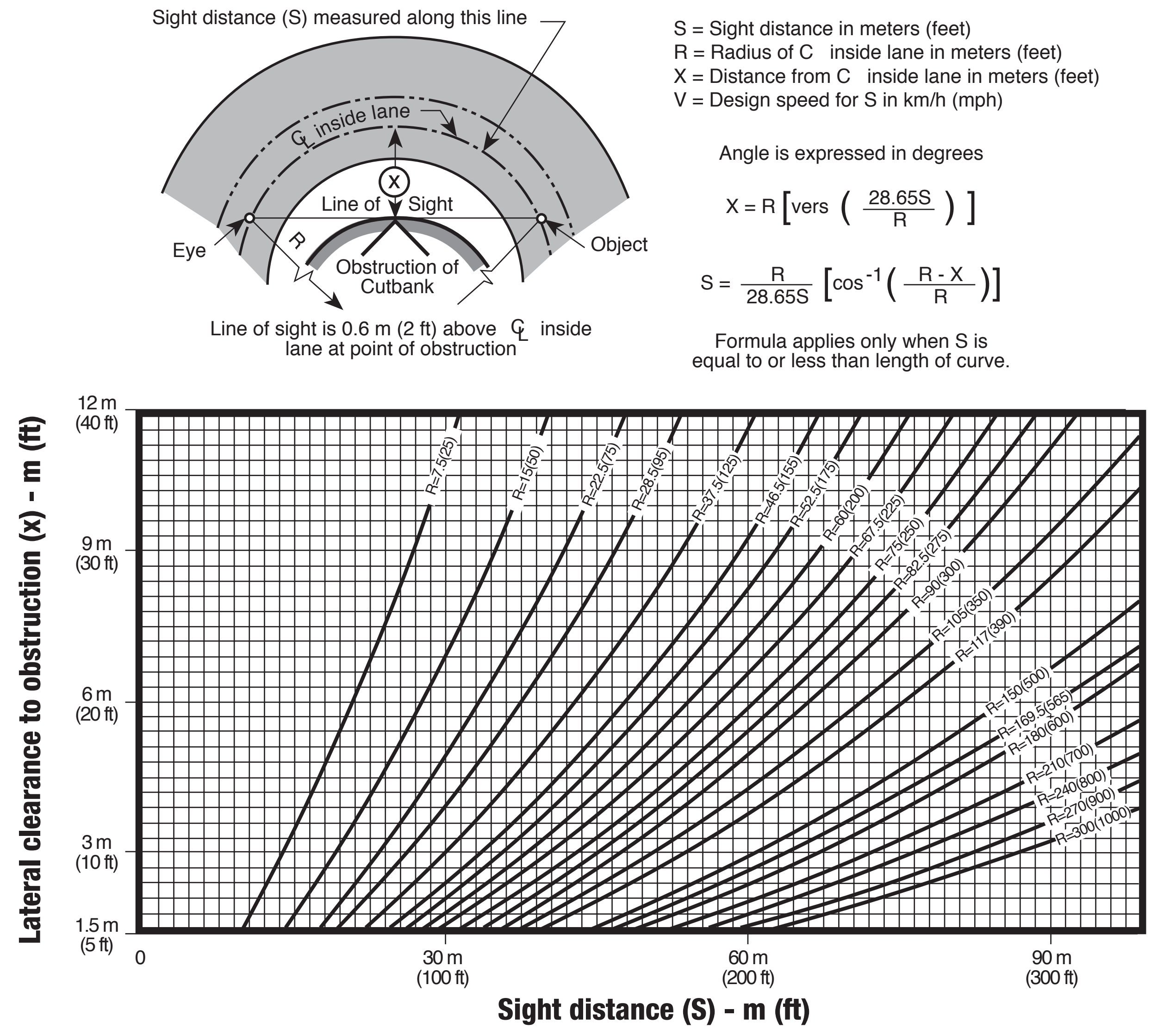


Figure 7-7: Lateral clearance on horizontal curves on bicycle paths.

Source: Guide for the Development of Bicycle Facilities; AASHTO, 1991

Sign type, size and location should be in accordance with the MUTCD. Care should be taken to ensure that bicycle path signs are located so that motorists are not confused by them and that highway signs are placed so that bicyclists are not confused by them.

If a bike path crosses a highway, such a crossing should occur well away from the influence of major intersections with other highways. Controlling vehicle movements at independent intersections is more easily and safely accomplished through the application of standard traffic control devices and normal rules of the road. Where signals are not warranted, consideration should be given to providing a median refuge area for crossing bicyclists. In this way, they can cross one direction of travel at a time.

Where physical constraints or high motor vehicle traffic volumes make crossing at such independent intersections difficult, the path may be brought to a nearby signalized intersection and the crossing made at or adjacent to the pedestrian crossing. Rights-of-way should be assigned and adequate sight distance should be provided so as to minimize the potential for conflict resulting from unconventional turning movements. It may be necessary to prohibit right-turn-on-red for the adjacent roadway and to provide a separate demand-actuated phase for the bicycle path.

Bicycle path intersections and approaches should be on relatively flat grades. Stopping sight distances at intersections should be checked and adequate warning should be given to permit bicyclists to stop before reaching the intersection, especially on downgrades.

Curb-cuts at intersections should be the same width as the bicycle paths. Curb-cuts and ramps should provide a smooth transition between the bicycle paths along the roadway.

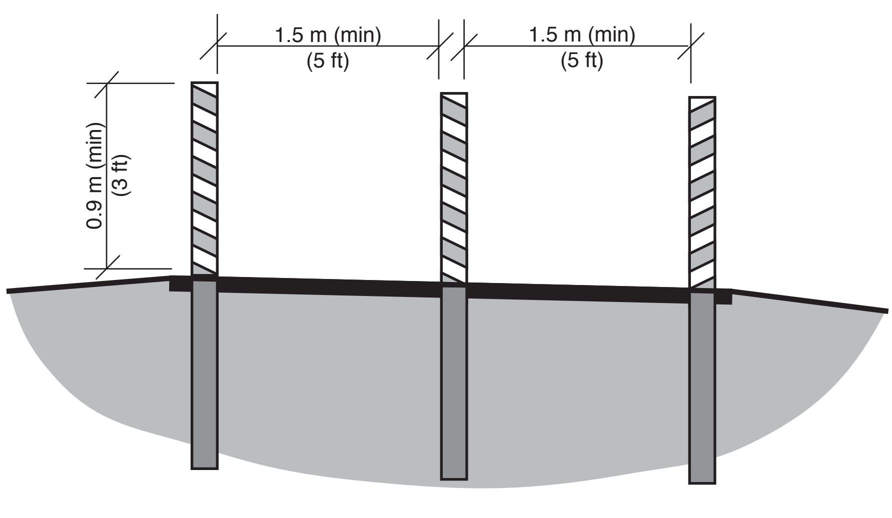
Restriction of motor vehicle traffic

Bicycle paths often need some form of physical barrier at highway intersections to prevent unauthorized motor vehicles from using the facilities. At the same time, the barrier should be designed to minimize the danger it poses for bicyclists and to allow the passage of emergency or maintenance vehicles. For this reason, proper materials, adequate design, good visibility and appropriate location are critical. While it is possible to restrict automobile and truck access, eliminating motorcycle access is very difficult. Barriers that can keep motorcycles out may make bicycle access difficult and potentially dangerous as well. At entrances to private driveways, motor vehicle barriers are less important than they are at highways. However, if a particular driveway is found to be a significant entry point for motorists, barriers should be considered there as well.

Lockable, removable posts at path entrances will allow entry of authorized vehicles. Posts should be at least 0.9 m (3 ft) high, permanently reflectorized for nighttime visibility and painted a bright color for improved daytime visibility. Their surface should be smooth and free of protrusions to prevent snagging a bicyclist's clothing or equipment.

To allow appropriate clearances, a 1.5 m (5 ft) spacing between posts should be used (see Figure 7-8). Wider spacing can allow entry to motor vehicles, while narrower spacing might prevent entry by adult tricycles and bicycles with trailers or present a hazard for less proficient bicyclists. On a 3 m (10 ft) path, the paving should be flared slightly and one post located near either edge and one post in the middle. A wider path will require more posts, again spaced at 1.5 m (5ft).

The barrier should be installed in a highly visible location with adequate sight distance from either direction. Lighting may be considered if the location has inadequate street lighting to illuminate the barrier. Marking an envelope around the barrier is recommended (see Figure 7-8). If sight distance is limited, special advance warning signs or painted pavement markings should be provided. It is best to locate the barrier 9 m (30 ft) from the



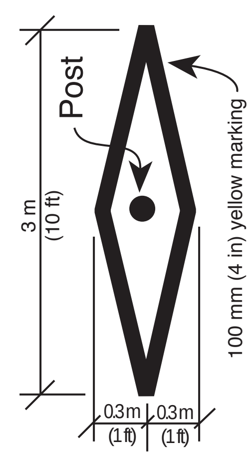


Figure 7-8: Reflectorized post barrier used to keep motor vehicles off bicycle paths and marking plan.

Source: California Highway Design Manual; CalTrans; 1987 intersection to allow bicyclists to pay full attention to traffic once they reach the crossing and to remove the barrier from the motorists clear recovery zone.

An alternative method of restricting entry of motor vehicles is to split the entry way for the last 3 m to 9 m (10 ft or 30 ft) before the intersection into two 1.5 m (5 ft) sections that enter the intersection approximately 1.5 m (5 ft) apart (see Figure 7-9). The sections may be separated and surrounded by low landscaping. Emergency vehicles can still enter if necessary by straddling the landscaping. The higher maintenance costs associated with landscaping should be acknowledged, however, before this alternative method is selected.

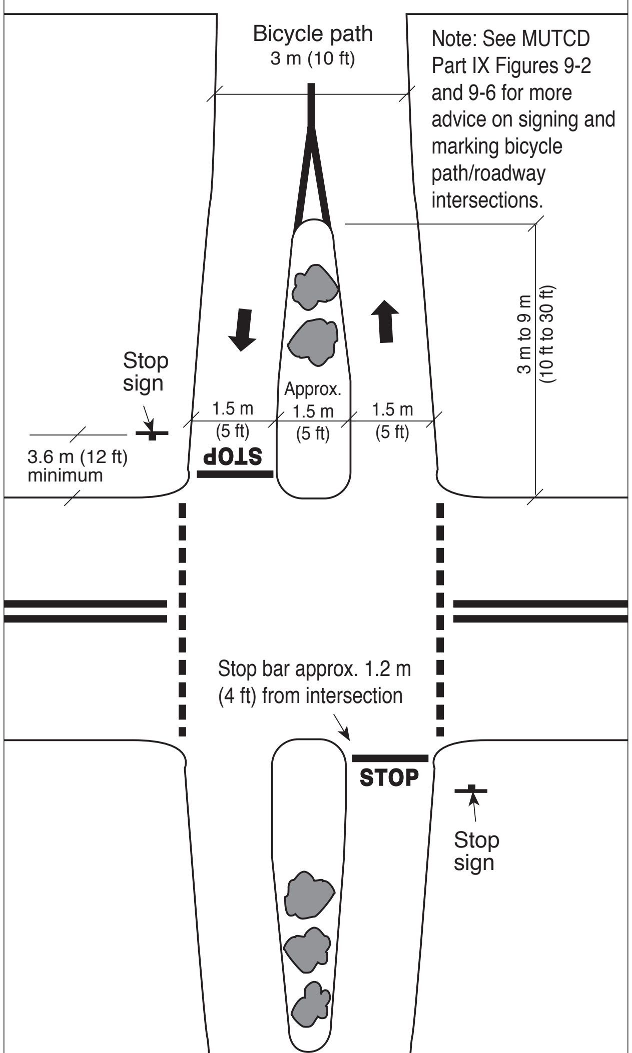


Figure 7-9: Alternative approach to bike path/roadway intersection. Source: Bicycle Facility Design; OHDOT; 1988

Whether the post or split entry method is used, pavement markings and signing may be used to warn bicyclists and direct them in the appropriate direction.

Bike path signing and marking

Adequate signing and marking are essential on bicycle paths, especially to alert bicyclists to potential hazards and to convey regulatory messages to both bicyclists and motorists at highway intersections. In addition, guide signing to indicate directions, destinations, distances, route numbers and names of crossing streets, should be used in the same manner as they are used on highways. In general, uniform application of traffic control devices will tend to encourage proper bicyclist behavior. When deciding whether to install a sign, the designer should ask whether he or she would install one on a roadway with a similar situation. Further, using standard rather than unique signs should reduce sign theft.

General guidance on signing and marking is provided in the MUTCD. Part IX of the MUTCD (reproduced in Appendix 4), refers specifically to traffic controls for bicycle facilities.

In order to keep signs from becoming hazards themselves, they should be offset horizontally from the edge of the bicycle path as shown in Figure 7-1.

A dashed 100 mm to 150 mm (4 in to 6 in) wide yellow center line should be used to separate opposite directions of travel. A solid double yellow center line should be used on curves, especially those with restricted sight distance. White edge lines, 100 mm to 150 mm (4" to 6"), also can be beneficial where significant night-time bicycle traffic is expected (e.g., near a university campus).

If a pedestrian area is to be designated, it should be separated from the bicycle path by at least a 100 mm to 150 mm (4 in to 6 in) solid white line (Figure 7-10). Regulatory signs (see sign R9-7 on page 80) also should be used. However, if space allows, a physical separation like a bicycle-safe barrier or a 0.9 m (3 ft) grassy berm is preferred (Figure 7-10).

In areas where pavement markings are found to be cost effective, consideration should be given to using them in conjunction

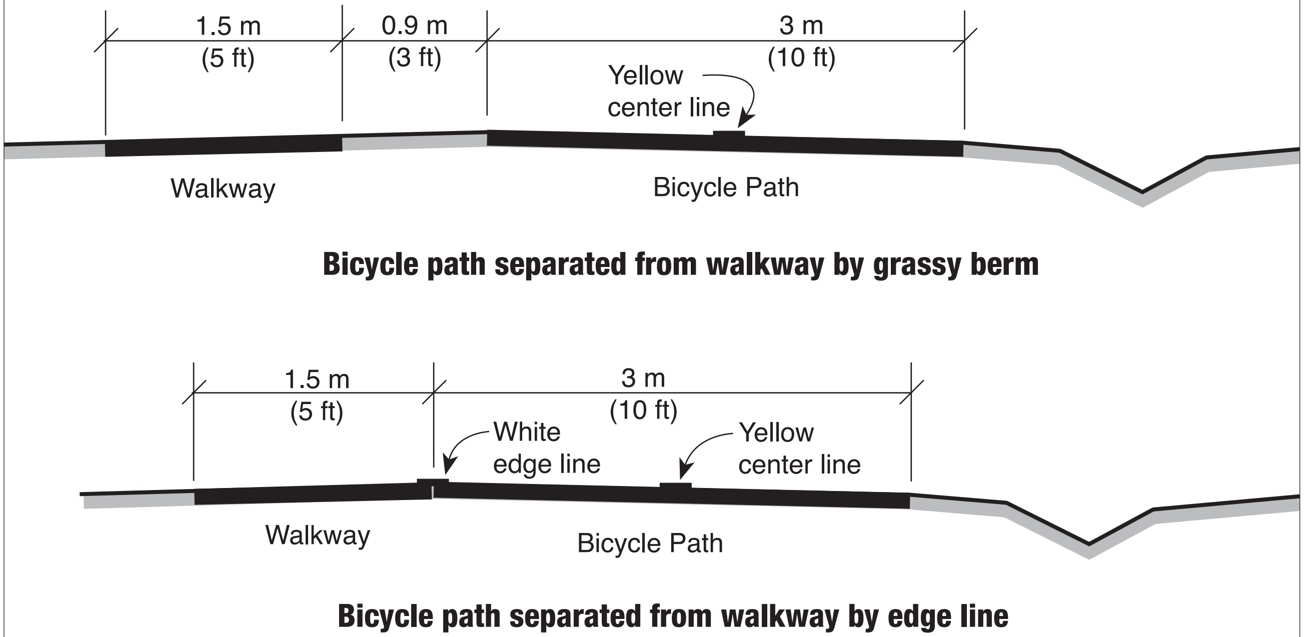


Figure 7-10: Two approaches to separating a bicycle path from a walkway.

with warning or regulatory signs, especially at critical locations. Otherwise, theft of warning or regulatory signs may result in bicyclists not being aware of serious hazards or their legal duties in a particular situation. Care should be exercised in the choice of pavement marking materials. Thermoplastic and preformed tape, for example, are slippery when wet and should be avoided in favor of more skid-resistant materials like traffic paint.

Whenever construction work is conducted on bicycle paths, it is important to sign, mark and, if necessary, barricade the construction zone with care as shown in the MUTCD, Part VI. If a detour is provided, it should be signed appropriately.

Pavement structure

Designing and selecting pavement sections for bicycle paths is in many ways similar to designing and selecting highway pavement sections. A soils investigation should be conducted to determine the load carrying capabilities of the native soil and the need for any special provisions. The investigation need not be elaborate, but should be done by, or under the supervision of, a qualified engineer.

In addition, several basic principles should be followed to recognize some basic differences between the operating characteristics of bicycles and those of motor vehicles. While loads on bicycle paths will be substantially less than highway loads, paths should be designed to sustain – without damage – wheel loads of occasional emergency, patrol, maintenance and other motor vehicles that are expected to use or cross the path.

Special consideration should be given to the location of motor vehicle wheel loads on the path. When motor vehicles are driven on bicycle paths, their wheels will usually be at or very near the edges of the path. Since this can cause edge damage that, in turn, will result in the lowering of the effective operating width of the path, adequate edge support should be provided. Edge support can be either in the form of stabilized shoulders or in constructing additional pavement width. Constructing a typical pavement width of twelve feet, where right-of-way and other conditions permit, eliminates the edge raveling problem and offers two additional advantages over shoulder construction. First, it allows additional maneuvering space for bicyclists, and second, the additional construction cost can be less than for constructing shoulders because the separate construction operation is eliminated.

It is important to construct and maintain a smooth riding surface on bicycle paths. Bicycle path pavements should be machine laid. Soil sterilants should be used where necessary to prevent vegetation from erupting through the pavement. And, on portland cement concrete pavements, transverse joints, necessary to control cracking, should be saw cut to provide a smooth ride. Skid resistance qualities, however, should not be sacrificed for the sake of smoothness. Broom finish or burlap drag concrete surfaces are preferred over trowel finishes. In areas where climates are extreme, the effects of freeze-thaw cycles should be anticipated. Geotextiles and other similar materials should be considered where subsurface conditions warrant.

At unpaved highway or driveway crossings of bicycle paths, the highway or driveway should be paved as far as practible on either side of the crossing to reduce the amount of gravel scattered along the path by motor vehicles.

The pavement structure at the crossing should be adequate to sustain the expected loading at that location.

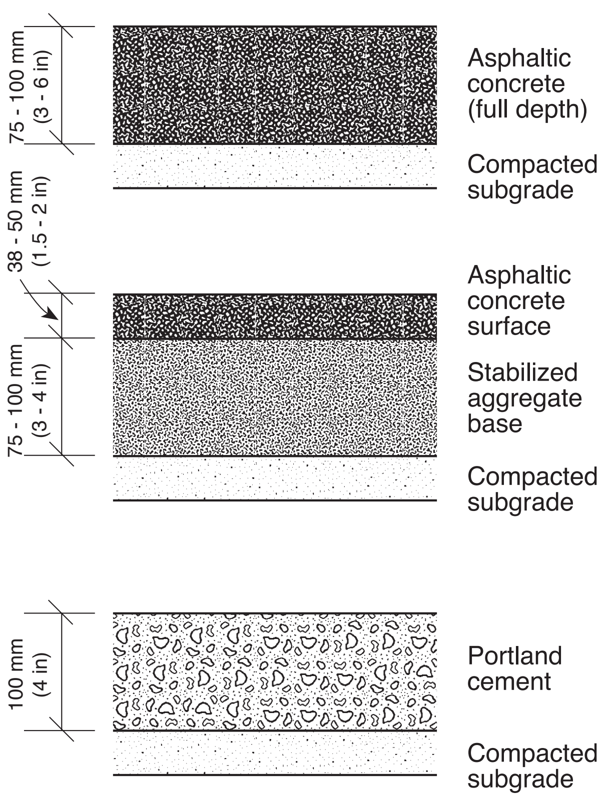


Figure 7-11: Typical pavement structural sections for bicycle paths.

Source: AZ Bicycle Facilities Planning & Design Guidelines; AZDOT, 1988

Good quality pavement structures can be constructed of asphaltic or portland cement concrete. Because of wide variations in soils, loads, materials and construction practices, it is not practical to present specific or recommended typical structural sections. Local standards for construction, preparation of sub-base and soil sterilization for a low-volume road should, in most cases, produce an adequate cross section for a bicycle path. However, Figure 7-11 shows some typical pavement structural sections.

Attention to the local governing conditions and to the principles outlined above is needed. Experience in highway pavement design, together with sound engineering judgment, can assist in the selection and design of a proper bicycle path pavement structure.

Hard, all-weather pavement surfaces are usually preferred over those of crushed aggregate, sand, clay or stabilized earth since these materials provide a much lower level of service. However, with the growth in popularity of mountain bikes, non-paved surfaces are being considered more frequently. With their wider lower-pressure tires, mountain bikes can easily handle surfaces that would prove unstable for thin-tired bikes. Further, an unpaved path will have a lower design speed, reducing the potential for conflicts between high-speed bicycles and low-speed pedestrians. The best surfaces for unpaved paths are crushed stone, stabilized earth or limestone screenings, depending upon local availability.

Utility covers and drainage grates should be flush with the pavement surface, and drainage grates should be designed to allow the crossing of bicycles from all angles. See Figure 4-1 on page 17 in the Roadway Improvements chapter for more details on grate design.

Railroad crossings should be smooth and should occur as close to 90 degrees to direction of travel as possible in order to minimize the danger of falls (Figure 7-12). Special rubberized crossings and flangeway fillers, as described in Figures 4-3 and 4-4 on pages 18 and 19, should be considered.

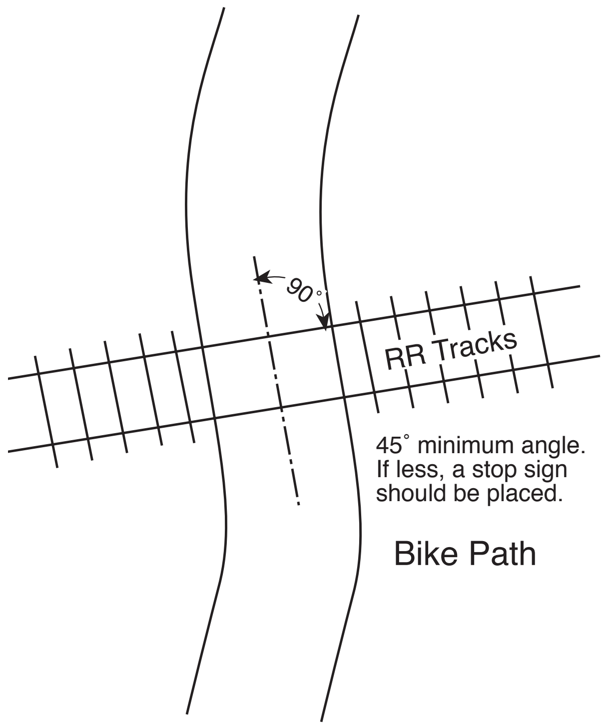


Figure 7-12: Bicycle path railroad crossing.
Source: AZ Bicycle Facilities Planning & Design Guidelines; AZDOT, 1988

Bike path structures

When a bicycle path meets a barrier – such as a railroad, a river or an interstate highway – some sort of grade-separated crossing may be necessary to provide continuity. This crossing may take the form of a bridge, an underpass or a facility on a highway bridge. On new bicycle structures, the minimum clear width should be the same as the approach paved bicycle path; and the desirable clear width should include the minimum 0.6 m (2 ft) wide clear areas on either side. Carrying the clear areas across the structures has two advantages: first, it provides a minimum horizontal shy distance from the railing or barrier, and second, it provides needed maneuvering space to avoid conflicts with pedestrians and other bicyclists who are stopped on the bridge.

Access by emergency, patrol and maintenance vehicles should be considered in establishing the design clearances of structures on bicycle paths. Similarly, vertical clearance also may be dictated by occasional motor vehicles using the path. However, where practical, a vertical clearance of 3 m (10 ft) is desirable for adequate vertical shy distance.

Independent bicycle bridges: Railings, fences or barriers on both sides of a bicycle path bridge should be a minimum of 1372 mm (54 in) high (Figure 7-13). Smooth 250 mm (10 in) tall rub rails may be attached to the barriers at a handlebar height of 1.1 m (3.5 ft). Ends of railings should be offset away from the adjoining path to minimize the danger of cyclists running into them (Figure 7-14). If this is not possible, Type II or Type III object markers, as described in the MUTCD Part IX, should be used.

Bridges designed for bicycle and/or pedestrian traffic shall be designed for a live load of 4070 Pa (85 psf). On concrete decks, care should be taken to ensure that bicycle-safe expansion joints are used. Broom finish or burlap drag surfaces are preferred over trowel finishes.

If planking is used for decking, the joints between boards should be smooth and at least 45 degrees to the direction of travel to prevent their diverting bicycle wheels. In addition, boards should be placed in such a way as to curl down rather than up.

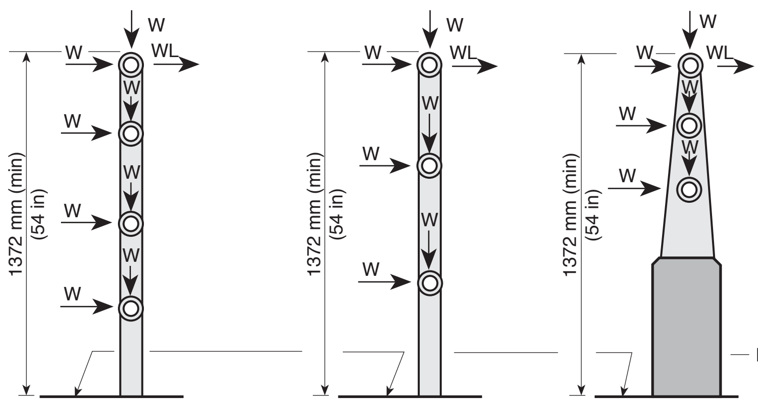
Bridges: If it is impossible to provide an independent bicycle bridge, one option is to retrofit a bicycle path onto one side of an existing highway bridge.

This should be done where:

- *The bridge facility will connect to a bicycle path at both ends;*
- *Sufficient width exists on one side of the bridge or can be obtained by either widening or restriping lanes;*
- *Provisions are made to physically separate bicycle traffic from motor vehicle traffic; and*
- *Any crossing difficulties with roadway turn ramps at either end can be overcome.*

Mounting a bicycle facility on an existing bridge requires that the bridge have sufficient strength to hold such a structure. An engineering study must be done to determine the safety of the proposed addition.

Merging a bicycle path onto the roadway at either end of the bridge, using either bicycle lanes or wide curb lanes, generally is not rec-



Note:

If screening or solid face is present, number of rails may be reduced; wind loads must be added if solid face is used.

Notes:

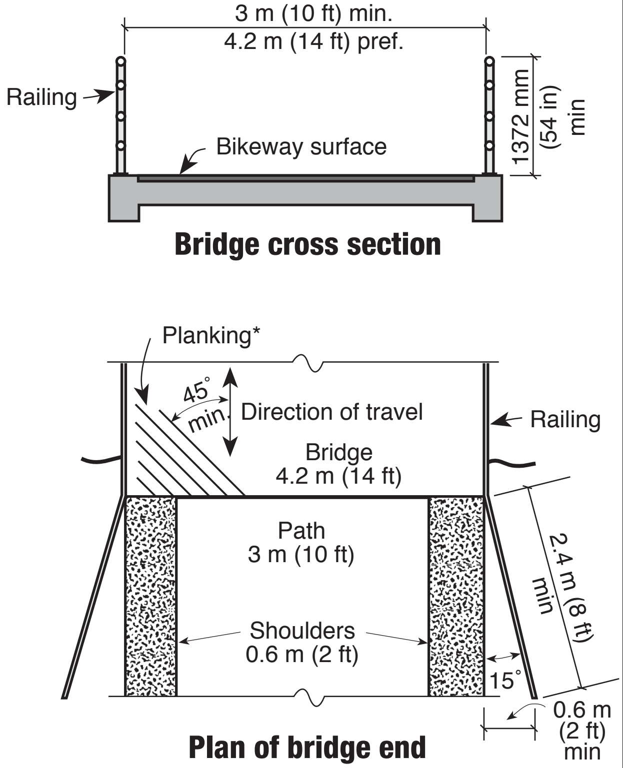
1. Loadings on left are applied to rails.
2. Loads on right are applied to posts.
3. The shapes of rail members are illustrative only. Any material or combination of materials listed in Article 2.7 (Standard Specifications for Highway Bridges) may be used in any con-

Figure 7-13: Alternative railing designs for independent bicycle bridges.

Source: Standard Specifications for Highway Bridges; AASHTO, 1989

ommended because of the likelihood that bicyclists will stay on that side of the bridge regardless of their direction of travel.

Sidewalks: Using existing sidewalks as two-way facilities is generally inadvisable. Because of the large number of variables involved in retrofitting bicycle facilities onto existing bridges, compromises in desirable design criteria are often inevitable. Therefore, the width to be provided is best determined by the designer, on a case-by-case basis, after thoroughly considering all the variables.



*If planking used, it must be laid at least 45° to direction of travel.

Figure 7-14: Bridge widths and clearances.

Underpasses and tunnels: In some cases, an underpass will be the best way to carry a bicycle path under a highway. Figure 7-15 shows a typical underpass cross section for bicycle paths. Lighting, grades, approaching curve design, visibility and maintenance should be carefully considered.

Drainage

The recommended minimum pavement cross slope of two percent adequately provides for drainage. Sloping in one direction instead of crowning is preferred and usually simplifies the drainage and surface construction. On curves, the cross slope should be towards the inside of the curve.

A smooth surface is essential to prevent water ponding and ice formation. Where a bicycle path is constructed on the side of a hill, a ditch of suitable dimensions should be placed on the uphill side to intercept the hillside drainage. Ditches and drainage structures should be designed so that they do not create hazards for bicyclists and should be offset from the edge of the path as described in the topic, Width and Clearance, on page 42. If drainage structures cannot be offset sufficiently, object markers should be used to warn bicyclists of their presence.

Where necessary, catch basins with drains should be provided to carry the intercepted water under the path. Drainage grates and manhole covers should be located outside of the travel path of bicyclists. To assist in draining the area adjacent to the bicycle path, the design should include considerations for preserving the natural ground cover. Seeding, mulching, and sodding of adjacent slopes, swales and other erodible areas should be included in the design plans.

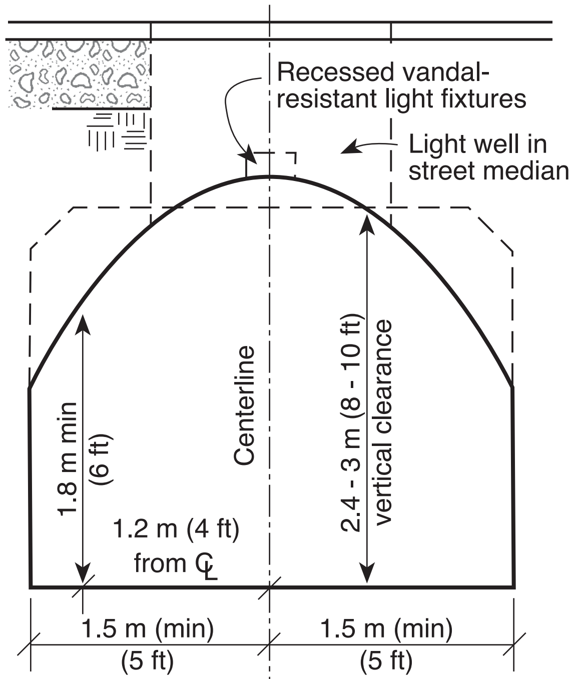


Figure 7-15: Bicycle path underpass.

Source: AZ Bicycle Facilities Planning & Design Guidelines; AZDOT, 1988

Lighting

Fixed-source lighting reduces conflicts along paths and at intersections. In addition, lighting allows the bicyclists to see the bicycle path direction, surface conditions and obstacles. Lighting for bicycle paths should be provided where considerable riding is expected at night, such as bicycle paths serving college students or commuters, where there is insufficient available light from the surrounding area, and at highway intersections, especially if there are post barriers that the cyclist must avoid. While the North Carolina motor vehicle laws require bicycles to have headlights after dark, the low level of lighting required by law won't necessarily light up a bicyclist's path sufficiently to see and avoid obstacles.

Each lighting situation is unique and must be dealt with on a case-by-case basis, however, average maintained horizontal illumination levels of 5 lux (0.5 foot candles) to 22 lux (2 foot candles) should be considered. Where special security problems exist, higher illumination levels may be considered. Light poles should be 3.6 m to 4.5 m (12 ft to 15 ft) high and must meet recommended horizontal clearances. Luminaires and poles should be at a scale appropriate for a pedestrian or bicycle path.

Underpasses and tunnels (except where there is a completely open view into the tunnel from the surrounding area) may need additional lighting, even in the day time, for both visibility and security. On bright, sunny days, bicyclists entering a dark underpass may be momentarily blinded and unable to see potential hazards; for this reason, they may need lighting to navigate safely.

Because lighting is important for cyclists' safety and security, vandal-resistant lighting fixtures are recommended in all locations.

Multi-use paths

Pedestrians: While multi-use paths may be undesirable due to the mixing of bicycles and pedestrians, in reality, most bicycle paths are multi-use to some extent. The degree of incompatibility between bicyclists and pedestrians is a function of density, speed, congestion and the presence of crossing and turning opportunities. The design of a multi-use trail should reflect consideration of each of these factors. Further, the more pedestrian traffic a trail receives, the less suitable it will be for bicycle traffic. In most situations, a multi-use trail with significant pedestrian traffic should not be designated as a bicycle trail.

Linear trails through greenbelts may have lower pedestrian densities—especially away from entry points and significant attractors (e.g., picnic areas and playgrounds)—and may suffice for multi-use if sufficient width is provided and adequate sight distances and clearances are maintained.

If higher pedestrian volumes are expected on a multi-use trail, as is the case in large urban areas, consideration should be given to providing a separate pedestrian trail adjacent to, but separated from, the bicycle trail. In some cases, a simple stripe between the pedestrian and bicycle areas may suffice. In others, providing a physical barrier and/or unpaved shoulder between may be necessary. (See Figure 7-10 for details.)

In areas with considerable congestion and diffuse patterns of pedestrian cross-traffic, a more appropriate design may be necessary. College campus "quads," for example, are very difficult situations in which to incorporate a bicycle facility. With pedestrians crossing in many places and at many angles, it is impossible to provide sufficient protection for the bicycle facility. In such situations, it may be more appropriate to direct bicycle traffic around the congested area and discourage fast bicycling within.

Mopeds: It also is undesirable to mix mopeds and bicycles on the same facility. Where it is necessary to do so, the facility should be designed to account for the higher operating speeds of mopeds, the additional maneuvering requirements of mopeds, and the increased frequency of passing maneuvers. Many of the design guidelines prescribed in this chapter (e.g., widths, design speeds, horizontal alignments, grades, etc.) would be inadequate for facilities intended for moped use.

Horses: Using a single path for bicycles and horses creates an unsatisfactory and potentially dangerous mix. Horses startle easily and may kick out suddenly if they perceive bicyclists as a danger. Two parallel paths within the same corridor, however, have been found to work well if there is a visual barrier and adequate separation between the two.